AD-A221 490

AD

TECHNICAL REPORT ARCCB-TR-90009

DENSIFICATION OF WEAPON CASTINGS

SANDRA O. ROY

DTIC
ELECTE
MAY 11 1990
S
B
D

MARCH 1990

US ARMY ARMAMENT RESEARCH,
DEVELOPMENT AND ENGINEERING CENTER
CLOSE COMBAT ARMAMENTS CENTER
BENÉT LABORATORIES
WATERVLIET, N.Y. 12189-4050

BENÉT
LABS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

90-05 10 048

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-90009	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DENSIFICATION OF WEAPON CASTINGS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Sandra O. Roy		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A72RCBQNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE March 1990
		13. NUMBER OF PAGES 30
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hot Isostatic Pressing
Densification
Muzzle Brakes
Porosity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The usage of hot isostatic pressing to effect closure of porosity is reviewed in this report. Evidence is presented showing that hot isostatic pressing is effective in eliminating internal porosity, thus resulting in a marked improvement in mechanical properties.

DD FORM 1473 1 JAN 73   EDITION OF 1 NOV 65 IS OBSOLETE

TABLE OF CONTENTS

TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

The Hot Isostatic Pressing (HIP) process had its origins in the mid-1950's when experiments were under way in both the United States and Sweden. These experiments included the diffusion bonding of nuclear parts and the removal of porosity in sintered tungsten carbide cobalt alloys (ref 1). Since then, HIP has been transformed into a production process for the manufacture and improvement of a vast range of different materials and components.

HIP is used for the densification of castings to provide internal soundness, increase densities, and improve mechanical properties. The HIP process works as follows: components are placed in a pressure vessel containing an inert gas, e.g., argon, where they are subjected to the simultaneous application of a high isostatic pressure and high temperature. A typical HIP system is illustrated in Figure 1. Under these conditions, the material becomes plastic and any internal voids collapse by creating a pressure differential between the voids in the workpiece and its external surface. HIP removes internal voids, in effect transferring the voids to the surface where the "dimple" is formed and can be machined away.

The effect of pressure collapses the voids while the effect of temperature speeds the process involved in the void removal. The shape of the component remains primarily unaltered because the forces causing the void pressure are equal in all directions (isostatic).

HIP does not usually affect dimensions if the voids and pores are small. Porosity typically can be eliminated as effectively in large castings as in small ones. Furthermore, castings with intricate shapes can be hipped as easily as those with simple shapes; the process is not shape-dependent.

1

Although HIP definitely has its advantages, it has a limitation. It cannot heal surface-connected defects because, as mentioned previously, the internal voids collapse by creating a pressure differential between themselves and the external surface. Generally, the chilled surfaces of castings are leaktight. Coatings are under development to provide high integrity surfaces when needed. One present method is the application of glass; it is already used to seal porous compact-powder preforms for HIP operations (ref 1).

PROBLEM

Frequently, weapon components with complex geometries produced as castings contain excessive voids and shrinkage cavities as a result of the casting process. Such defects can impair the ductility and toughness of these components resulting in unacceptable property levels and quality control rejection. Occasionally, the rate of rejection is very high in certain components necessitating a considerable amount of weld repair if the components are salvageable.

PROCEDURE

A "Known Closure Test" was initially conducted on material representative of muzzle brakes. This test was performed in order to determine the HIP parameters required in this material. The parameters included time, temperature, and pressure.

Four specimens were made utilizing 4130 barstock. These specimens are illustrated in Figures 2a and 2b, including two specimens which were sectioned from a 155-mm M185 muzzle brake casting as illustrated in Figures 3a and 3b. This test was carried out by producing (machining) holes of various diameters and lengths on both ends of a sound specimen (Figures 4a and 4b). The lengths and diameters of the holes are listed below in Table I.

TABLE I. LENGTHS AND DIAMETERS OF HOLES IN TEST SAMPLES

+ diameter (inches)	1/32	3/64	1/16	1/8	3/16	1/4
Depth for side 1 (inches)	3/8	7/16	14/16	1	1	1
Depth for side 2 (inches)	3/8	7/17	1/2	1/2	1/2	1/2

These holes were then evacuated and resealed by electron beam welding to simulate internal porosity conditions in a casting. Radiography was conducted on all samples prior to hipping (see Figures 5a and 5b). The specimens were then hipped under several processing conditions to eliminate the various size pores. Time, temperature, and pressure data were selected to close the internal "flaws" of the specimens.

The parameters selected for the HIP process for these specimens are listed in Table II.

TABLE II. PARAMETERS SELECTED FOR THE HIP PROCESS

Item	Temperature (°F)	Pressure (Ksi)	Time (Hrs)
Coupon #1	2000	15	2
Coupon #2	2000	15	4
Metal Casting #1	2000	15	4
Coupon #3	2000	15	6
Coupon #4	2000	15	8
Metal Casting #2	2000	15	8

Radiography was also conducted on the samples after the HIP process was conducted. All of the known holes in the metal castings and the coupons had been completely closed (see Figures 6a and 6b).

These parameters were then utilized on three 155-mm M199 muzzle brakes, with relatively high porosity levels of radiographic level 4 or greater (as per ASTM Standard E-446), for experimental closure purposes. Figure 7 illustrates one of the muzzle brakes used for experimentation. Since densification of the "Known Closure Test" samples occurred under all HIP conditions, we varied the time parameter for muzzle brakes 1, 2, and 3 as shown in Table III.

TABLE III. PARAMETERS USED FOR DENSIFICATION OF MUZZLE BRAKES

Item	Temperature (°F)	Pressure (Ksi)	Time (Hrs)
Muzzle Brake 1	2000	15	2
Muzzle Brake 2	2000	15	4
Muzzle Brake 3	2000	15	6

Prior to hipping, appendages from each brake were machined off and heat treated according to the contractor's specifications.

After the HIP process, radiographs were taken of each brake and sequentially heat treated. The heat treatment was conducted as follows:

1. Normalize at 1700°F for 2 hours and air cool.

2. Austenitize at 1700°F for 2 hours.

3. Hold at 1600°F for 1/2 hour and water quench.

4. Temper at 1040°F for 3 hours then water quench.

Subsequently, standard tensile and Charpy impact specimens were machined from the muzzle brake appendages (identified as HIP and No-HIP). The tensile properties were evaluated at room temperature, while the Charpy behavior was

evaluated at -40°F. The specimens were then metallographically examined in both the etched and unetched conditions.

The results from the no-HIP and the HIPPED material were then compared to each other. In addition, the HIPPED data were compared to the drawing requirements and mechanical properties of typical as-received muzzle brakes.

RESULTS

Radiographic Inspection

Figures 5a and 5b depict radiographs of the "Known Closure" specimens: the barstock and the muzzle brake (155-mm M185) casting material, respectively, prior to the HIP process. After the HIP process, radiographs were again taken to gauge the effect of the HIP experiment. The "after HIP" radiographs revealed all test holes were completely eliminated. These holes are representative of gross porosity, up to and greater than ASTM Standard E-446 level 5.

Radiographs of the muzzle brakes taken prior to HIP reveal extensive shrinkage and porosity as shown in Figure 8a. After HIP, the macroshrinkage still existed, as shown in Figure 8b. This indicates that these flaws were likely surface-connected and therefore difficult to close.

Mechanical Properties

The mechanical property test results are summarized in Tables IV through VI. The hipped material shows a significant increase in ductility, with percent elongation (EL) and percent reduction of area (RA) increasing substantially compared to the no-HIP method. An increase of 40 percent in percent RA and an increase of 20 percent in percent EL were obtained. The yield strength, hardness, and Charpy values for both sets of material were virtually identical.

5

Although muzzle brake 1 underwent 2 hours of hipping, muzzle brake 2 underwent 4 hours of hipping, and muzzle brake 3 underwent 6 hours of hipping, the time difference had no apparent impact on mechanical properties.

TABLE IV. NO-HIPPED MUZZLE BRAKE DATA

Muzzle Brake	YS (Ksi)	UTS (Ksi)	% RA	% EL	Cv (ft-lbs)	HRC
1	144	156	27	13	26	28
2	144	154	29	13	28	32.5
3	144	154.5	34	14.6	28	30

TABLE V. HIPPED MUZZLE BRAKE DATA

Muzzle Brake	YS (Ksi)	UTS (Ksi)	% RA	% EL	Cv (ft-lbs)	HRC
1	141	156	51-55	17.9-20.0	27-30	32.6
2	143.4-144	156.6-157.8	49	16.4	25	34
3	142.5-144	157.5-159.6	45.7-47.8	15.7-16.4	21-22	32.5

TABLE VI. MECHANICAL PROPERTY SPECIFICATIONS FOR 155-MM M199

	YS (Ksi)	% RA	Cv (ft-lbs)
Drawing Requirements per Drawing	130-139.9	30 min.	25 min.
No. 11578888	140	25 min.	20 min.

Metallography

Microstructural examinations were performed on the mechanical test specimens taken from the HIP and no-HIP muzzle brakes. A representative photomicrograph (Figure 9a) of the no-HIP samples reveals a material that contained shrinkage porosity, and was relatively large on a microscopic level with small globular oxide inclusions dispersed throughout the matrix. The HIP sample shows that densification was achieved on a microscopic scale, i.e., no evidence of shrinkage porosity (Figure 9b). Examination of the microstructures of both the no-HIP and HIPPED samples etched in 2 percent Nital shows tempered martensitic structures, Figures 10a and 10b. These microstructures are indicative of low alloy steel which has undergone quenching and tempering. The similar microstructures were attributed to the muzzle brakes, HIPPED and no-HIP, undergoing identical heat treatment.

Scanning Electron Microscopy

Stereoscopic and scanning electron microscopic (SEM) examinations were conducted on the fracture surfaces of the as-tested tensile bars from representative samples of the HIP and no-HIP muzzle brakes. The overall fracture surfaces of each are depicted in Figures 11a and 11b. The HIP sample fracture surface was a partial cup-cone fracture. It is a common feature of ductile fracture, occurring primarily by microvoid coalescence at the center of the bar and then by shear at the outside surfaces, and is manifested fractographically by dimples. Figure 11c shows the ductile fracture mode, referred to as dimpling, in the HIP sample.

Fracture surface features of the no-HIP samples were much coarser. There was also evidence of secondary cracking below the fracture surface. Upon examination at higher magnification, shrinkage porosity was noted on the fracture

surface with grain boundaries clearly visible inside these pores (see Figure 11d). The shrinkage cavities are a result of the solidification process.

DISCUSSION

The radiographic inspection of the three hipped muzzle brakes showed incomplete densification on a macroscopic level. The three muzzle brakes had undergone HIP utilizing the same pressure and temperature parameters, but the third parameter, time, was different for each one. Radiographs taken of muzzle brake 1 were similar to those of both muzzle brakes 2 and 3. This signifies that the amount of time the muzzle brakes remained at temperature (varying from 2 to 6 hours) had little effect on the material. The mechanical property results for the three muzzle brakes support this observation also. The data from the mechanical property tests taken from the hipped brakes show similar results for percent RA and percent EL. Yield strength, ultimate tensile strength, hardness, and Charpy values were also similar.

The gross shrinkage porosity observed in the muzzle brakes after HIP strongly suggests that this shrinkage was surface-connected. No realistic increase of time in the HIP vessel would have densified these flaws.

The mechanical property results of the hipped muzzle brakes were quite impressive with substantial increases in percent RA and percent EL compared to the no-HIP brakes. These specific properties reveal a significant increase in ductility.

The hipped muzzle brakes far surpass the percent RA drawing requirements (Table VI) of 25 percent minimum. In addition, there was an increase of 40 per-cent RA and an increase of 20 percent EL in hipped material over the no-HIP material.

8

The metallurgical evaluation showed a sharp reduction in microporosity and microshrinkage after HIP. This observation corroborates the mechanical property results. The improved mechanical properties were associated with the muzzle brakes undergoing the HIP operation process. As the microporosity and microshrink become virtually eliminated by the HIP process, the resultant material is more sound, yielding improved mechanical properties, particularly ductility.

CONCLUSION

Based on the tests performed on the 4130 "Known Closure Test" samples and the 155-mm M185 muzzle brake castings, the results of this investigation demonstrate that hipping is capable of upgrading mechanical properties and improving internal soundness in high strength low alloy steels. However, the radiographic analysis showed that when gross, surface-connected shrinkage existed in the muzzle brakes, the densification process did not effectively eliminate them. It was initially demonstrated in this study that large holes simulating gross porosity could be "healed" in the "Known Closure Test" sample as long as the following conditions were met: (1) holes were clean - vacuum conditions, and (2) all air was evacuated, and (3) sealed from the surface. These conditions are representative of the internal porosity, both shrinkage and gas, that typically occurs in castings.

This process can result in the salvage of unsatisfactory quality castings, an upgrading of mechanical properties for purposes of specification compliance, and substantial improvement in radiographic inspection capability. It cannot, however, remove or eliminate surface-connected porosity. If such a condition of porosity can be identified, one may take steps to seal this, e.g., ceramic glasslike coatings, prior to HIP if the casting appears otherwise salvageable.

9

REFERENCES

1. H.D. Hanes and J.M. McFadden, "HIP'ing of Castings: An Update," <u>Met. Prog.</u> Vol. 123, No. 5, April 1983, pp. 23, 26-28, 31.

BIBLIOGRAPHY

1. K. Brookes, "Hot Isostatic Pressing--The Modern Way," <u>Met. Powder Rep.</u>, Vol. 37, No. 8, August 1982, pp. 420-423.

2. B.A. Rickinson and J.C. Thompson, "Applications of Hot Isostatic Pressing to Ferrous and Non-Ferrous Metal Castings," in: <u>Second International Conference on Isostatic Pressing</u>, Vol. 1, Metal Powder Report Publishing Services, U.K., 1982, pp. 17.1-17.19.

3. P. Price, "Hot Isostatic Pressing--A New Heat Treatment Technology With Tremendous Potential," <u>Ind. Heat.</u>, Vol. 46, No. 6, June 1979, pp. 8-10.

4. R.R. Irving, "Hipping is One Way to Check Porosity in Cast Components," <u>Iron Age</u>, Vol. 225, No. 33, 19 November 1982, pp. 43-45.

5. "Hot Isostatic Pressing Can Heal Casting Voids. H.I.P. (Powder Metals) Ltd. Offer Contract Service," <u>Foundry Trade J.</u>, Vol. 152, No. 3235, 8 April 1982, pp. 463-464, 489.

6. J.L. McCall and K.E. Meiners, "Use of Hot Isostatic Processing to Eliminate Casting Defects," <u>Steel Founders' Res. J.</u>, Vol. 1, First Quarter 1983, pp. 15-21.

7. E.L. Rooy, "Improving Casting Properties and Integrity with Hot Isostatic Processing," <u>Mod. Cast.</u>, Vol. 73, No. 12, December 1983, pp. 18-20.

8. Peter Thornton, John Senick, and John Atchinson, "Mechanical Property Development in Hot Isostatic Pressed (HIP) Low Alloy Steel Powder," ARDC Technical Report, ARCCB-TR-86005, Benet Weapons Laboratory, Watervliet, NY, January 1986.

9. G.E. Wasielewski and N.R. Lindblad, "Elimination of Casting Defects Using HIP," <u>Superalloys--Processing. Proceedings of the Second International Conference</u>, Metals and Ceramics Information Center Report MCIC-72-10, Battelle Columbus Labs, Ohio, September 1972.

10. V. Colangelo and F. Heiser, <u>Analysis of Metallurgical Failures</u>, John Wiley & Sons, Inc., New York, 1974.

UPPER COVER

COOLING JACKET

155MM M199
MUZZLE BRAKE

HEATER

THERMOCOUPLE

PRESSURE VESSEL

POWER CONNECTION

LIQUID
ARGON
STORAGE

VACUUM PUMP

TRANSFER PUMP

OVER
PRESSURE
RELEASE

INTERFACE

COMPUTER

POWER   CONTROLLER

LIQUID PUMP

EXHAUST
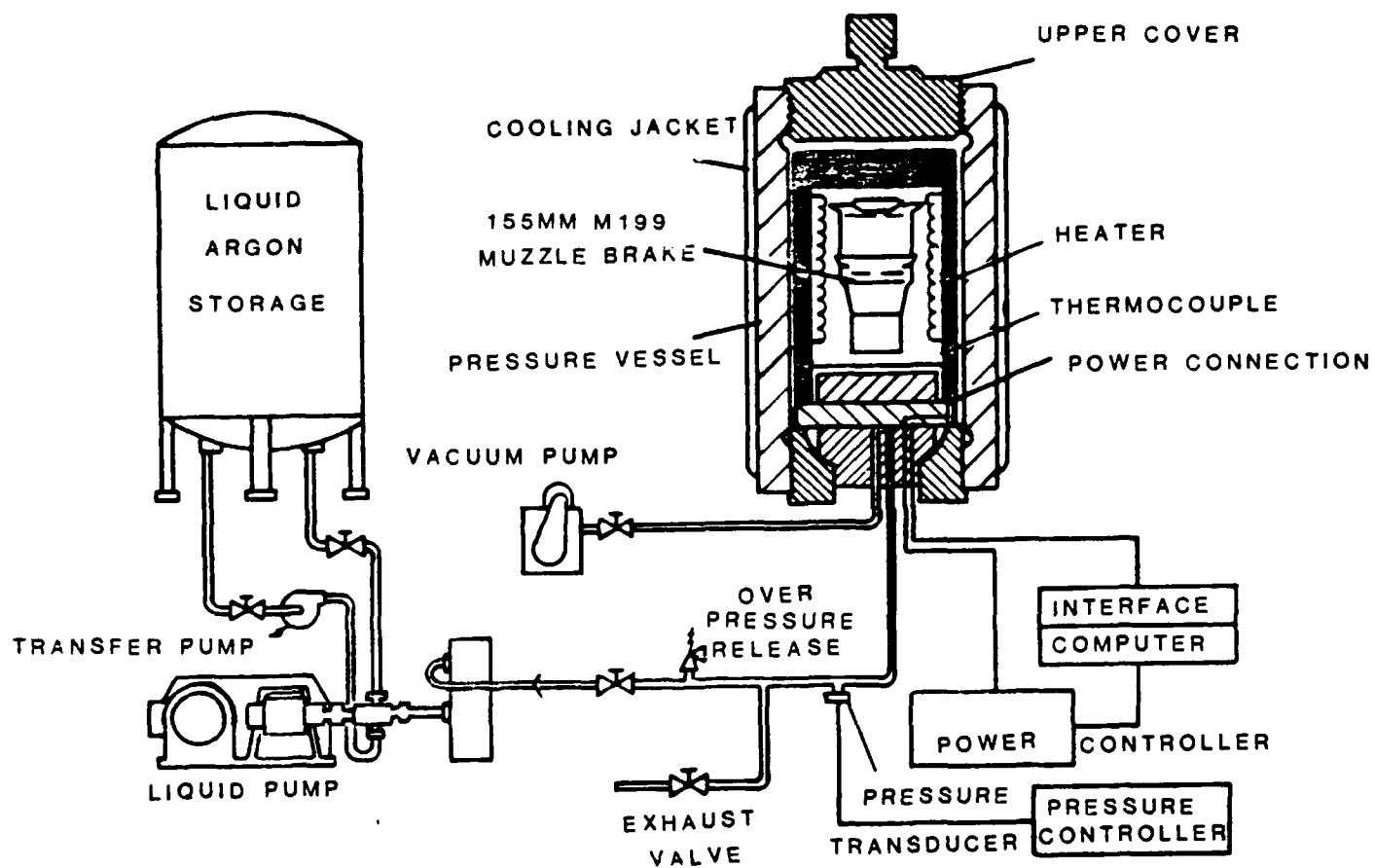VALVE

PRESSURE

TRANSDUCER

PRESSURE
CONTROLLER

Figure 1. Simplified schematic of a hot isostatic pressure system.
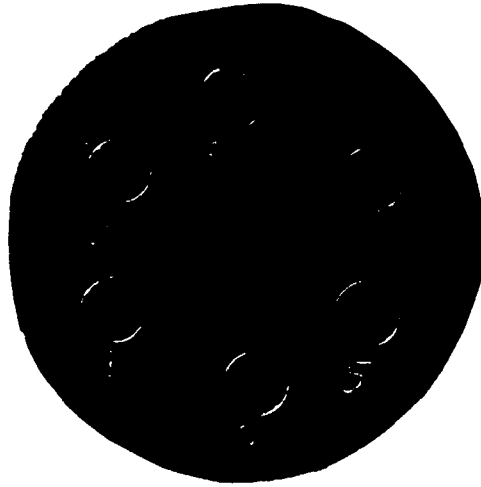
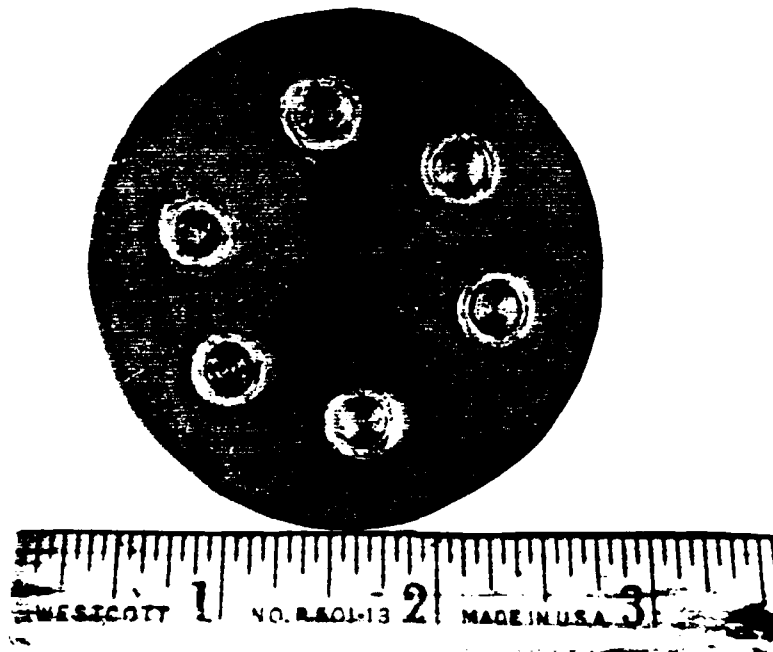Figure 2a. Top view of barstock showing holes drilled into surface.

Figure 2b. Holes resealed by electron beam welding.

Figure 3a. Muzzle brake casting specimen showing
holes drilled into top surface.
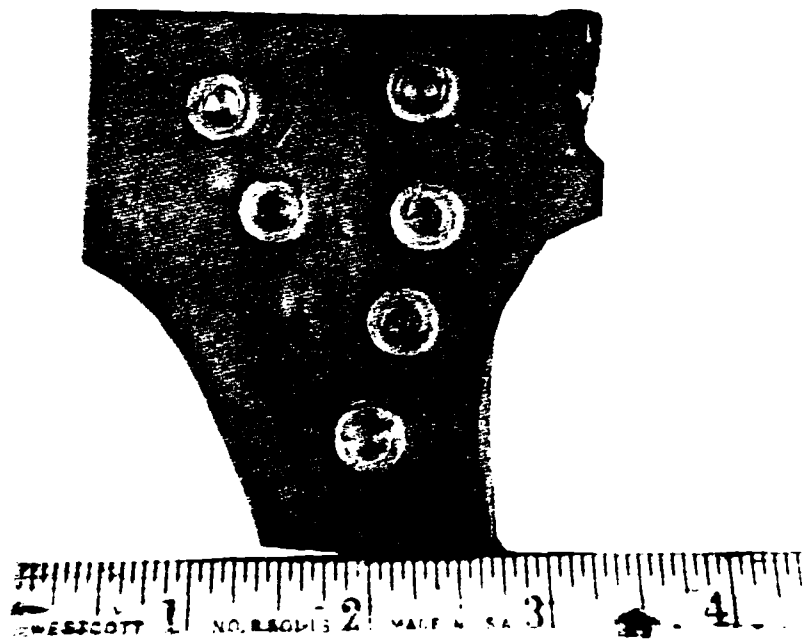
Figure 3b. Resealed holes on top surface
of brake casting specimen.
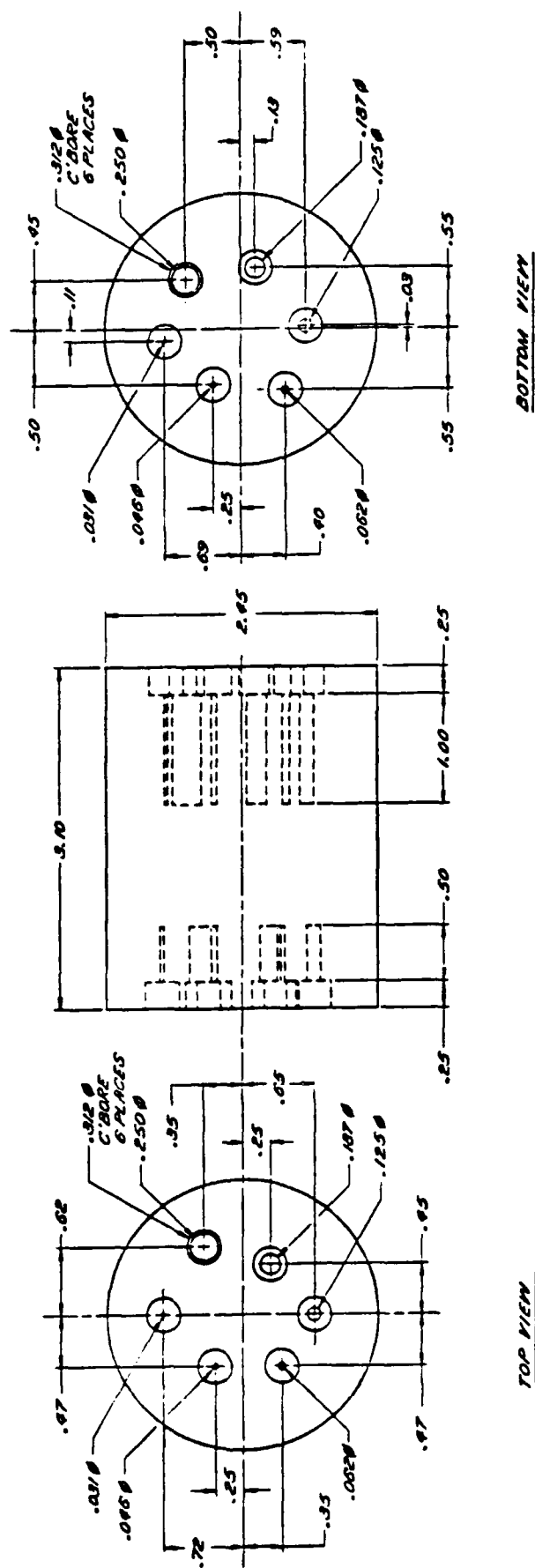
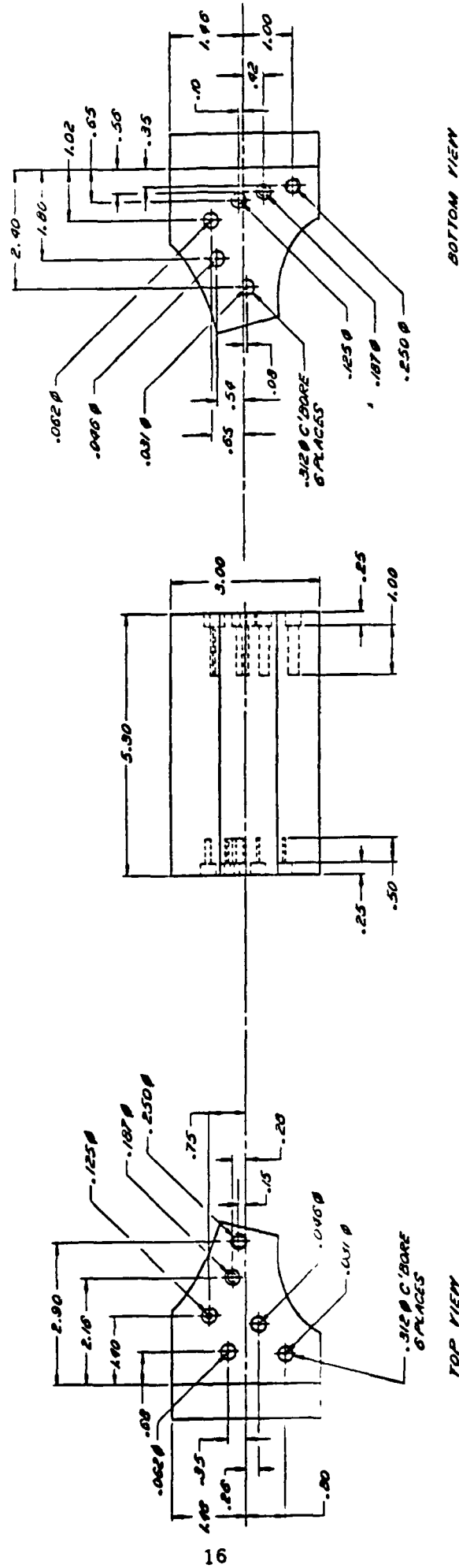Figure 4a.   Diagram of barstock showing machined holes.

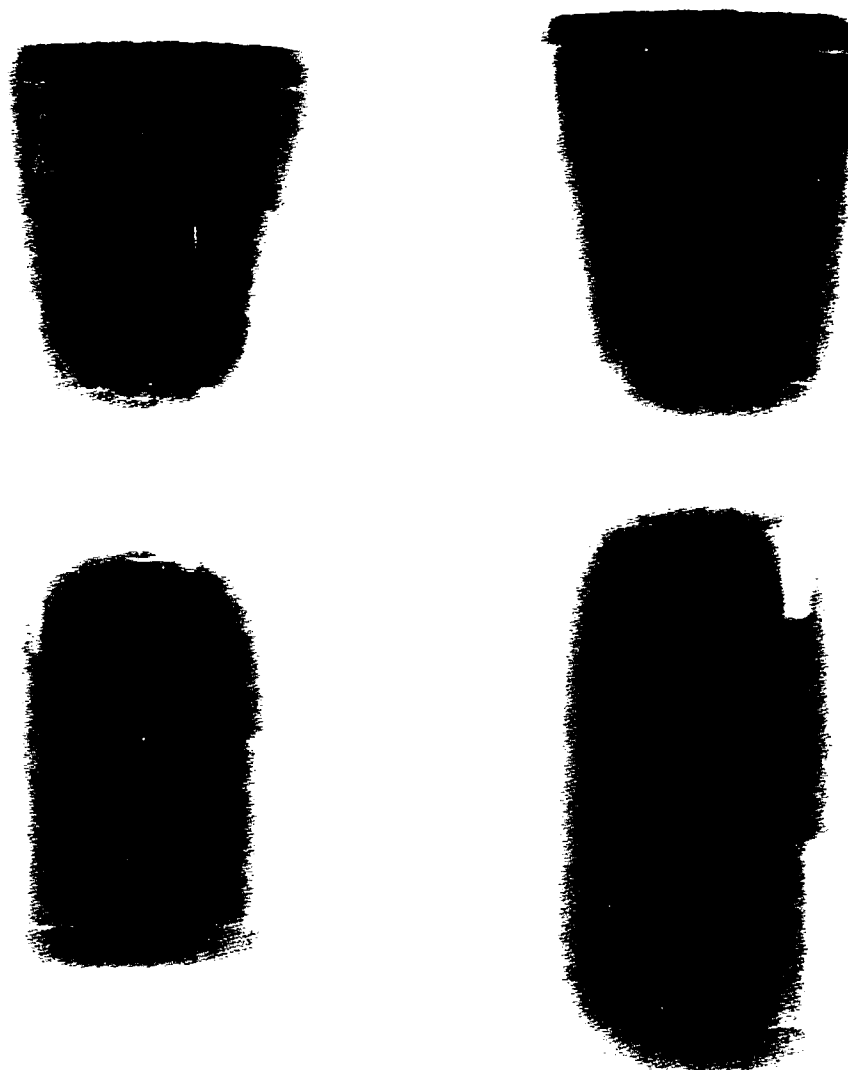Figure 4b. Diagram of casting showing machined holes.

16

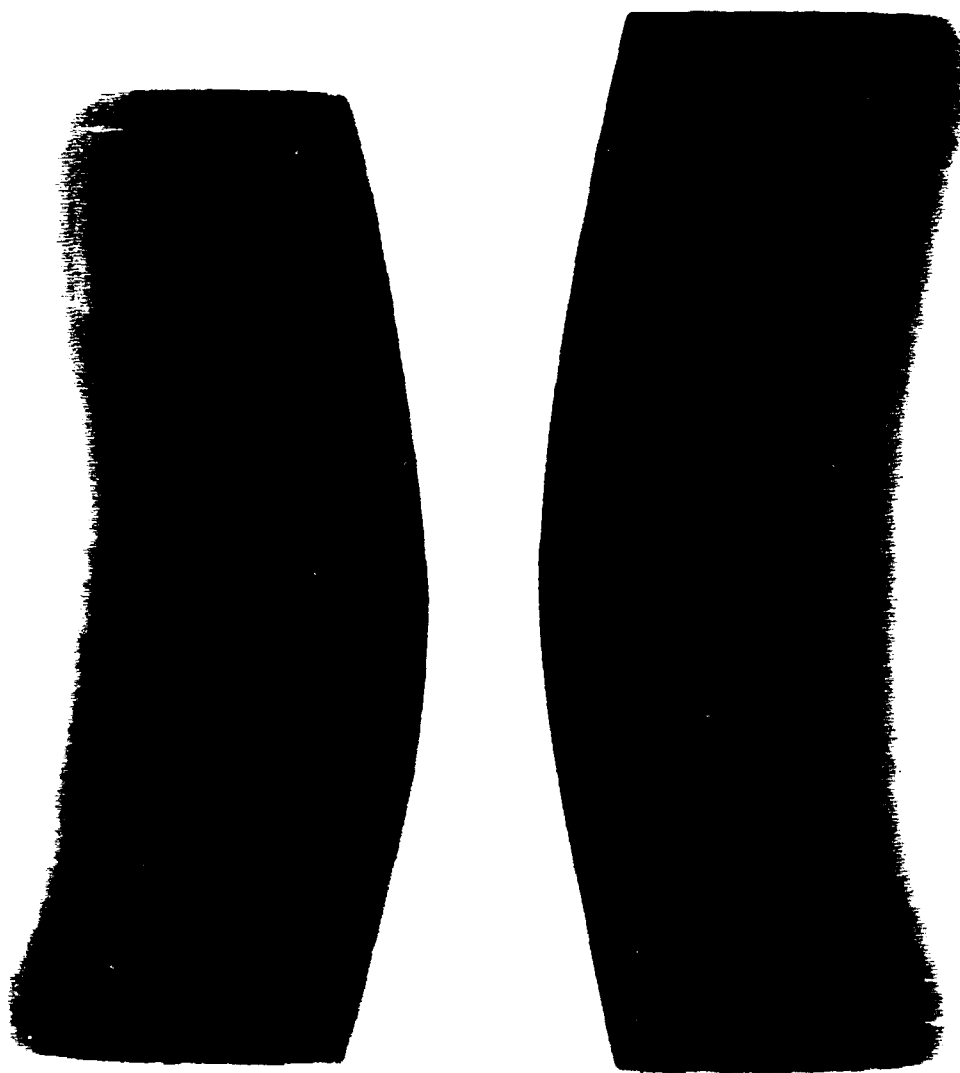Figure 5a. Radiograph of barstock samples taken prior to HIP.

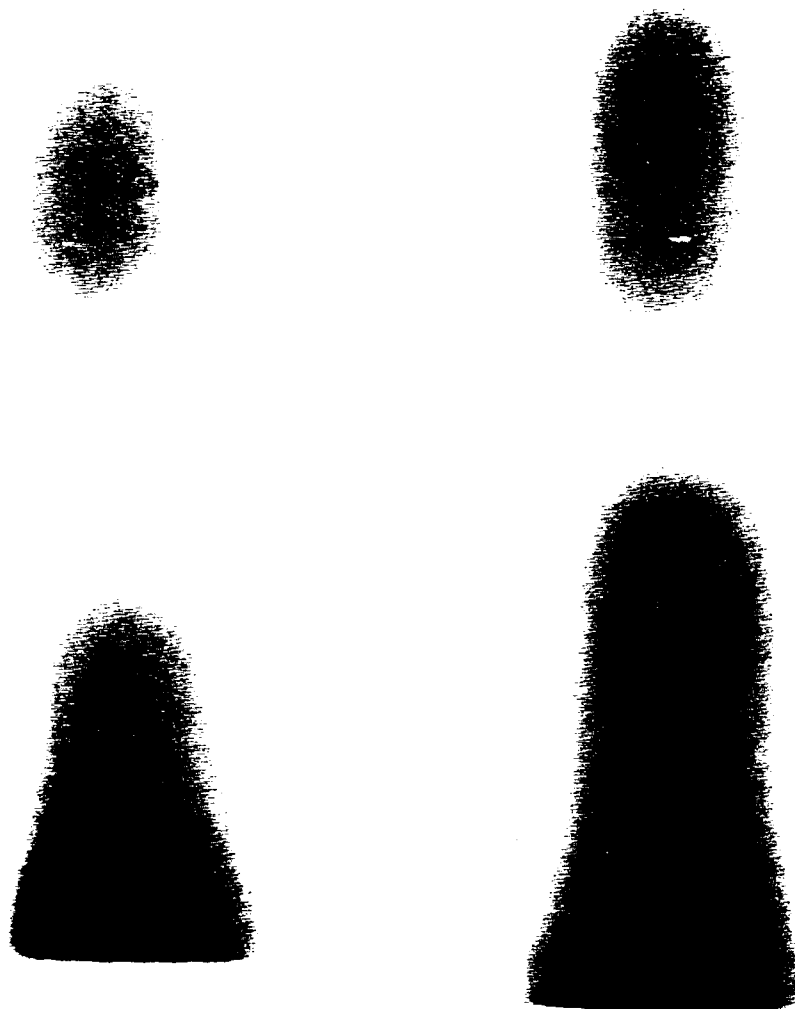Figure 5b.   Radiograph of casting samples taken prior to HIP.

Figure 6a. Radiograph of barstock samples after HIP.

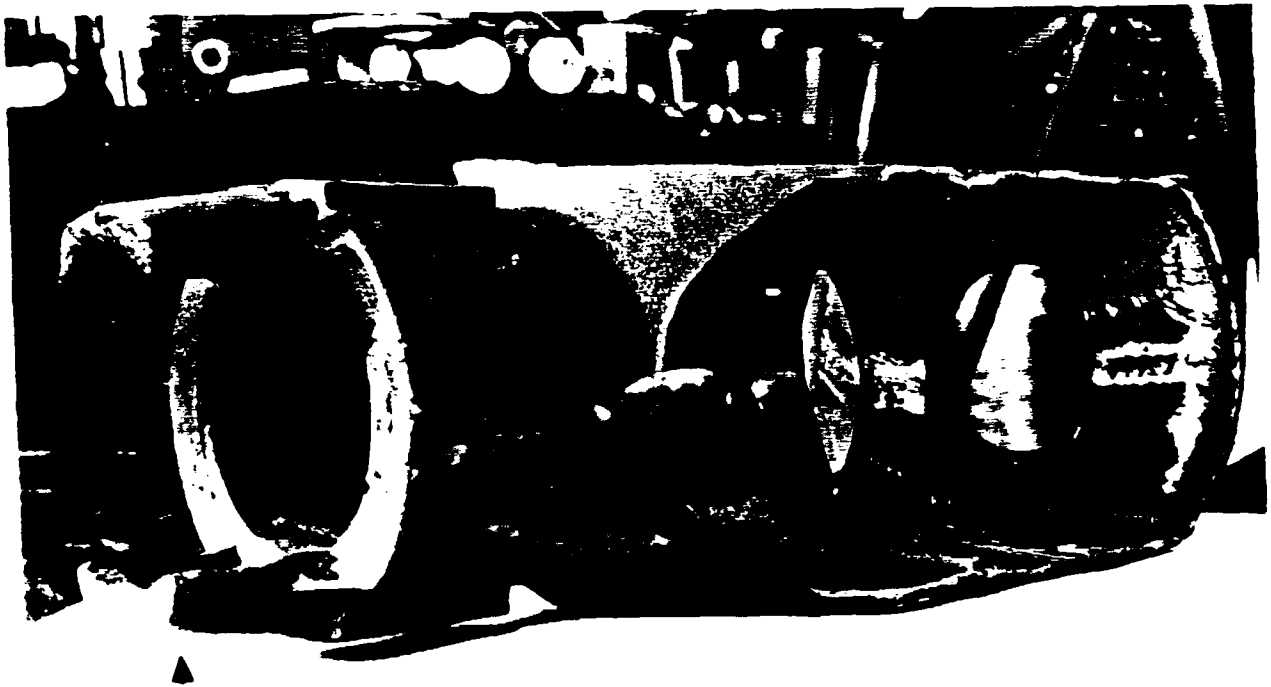Figure 6b. Radiograph of casting sample after HIP.

20

Figure 7.   155-mm M199 muzzle brake casting used for experimentation.
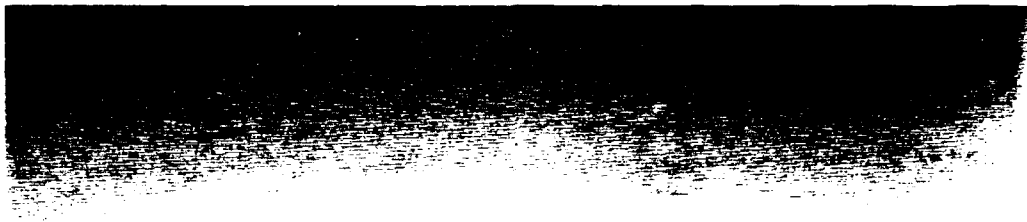Arrows point to appendages.

Figure 8a. Radiograph of muzzle brake section taken
prior to HIP showing severe shrinkage.

Figure 8b.   Radiograph of muzzle brake section taken
after HIP showing severe shrinkage.
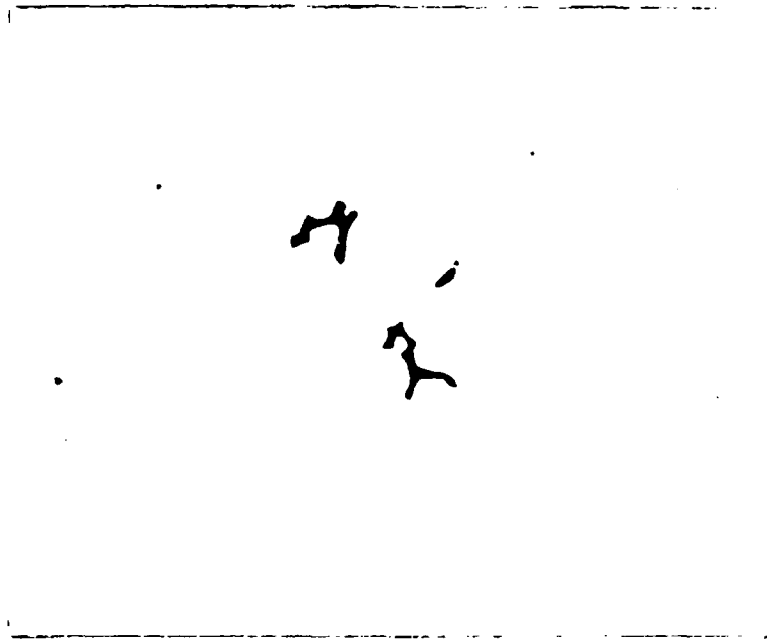
Figure 9a.   Photomicrograph depicting microshrinkage
             porosity prior to HIP (100X).
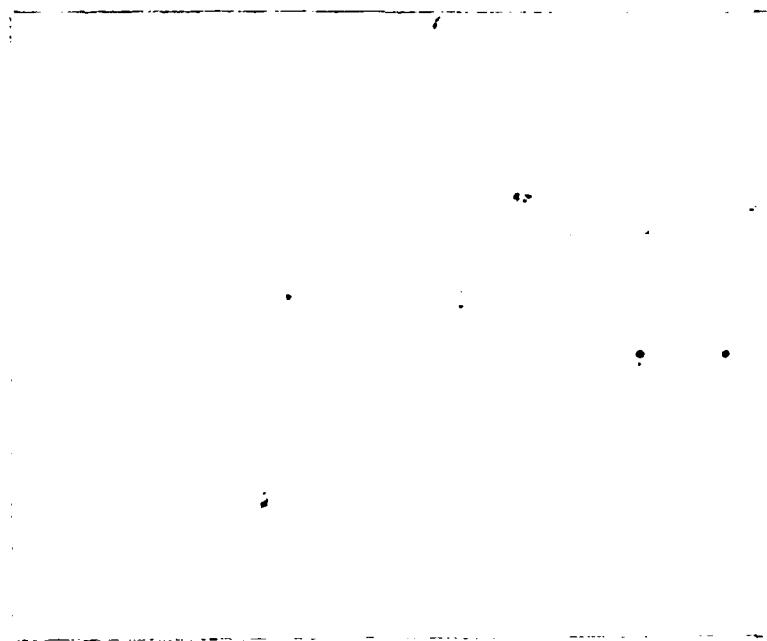

Figure 9b.   No evidence of shrinkage porosity appearing
             in the post-HIP sample (100X).
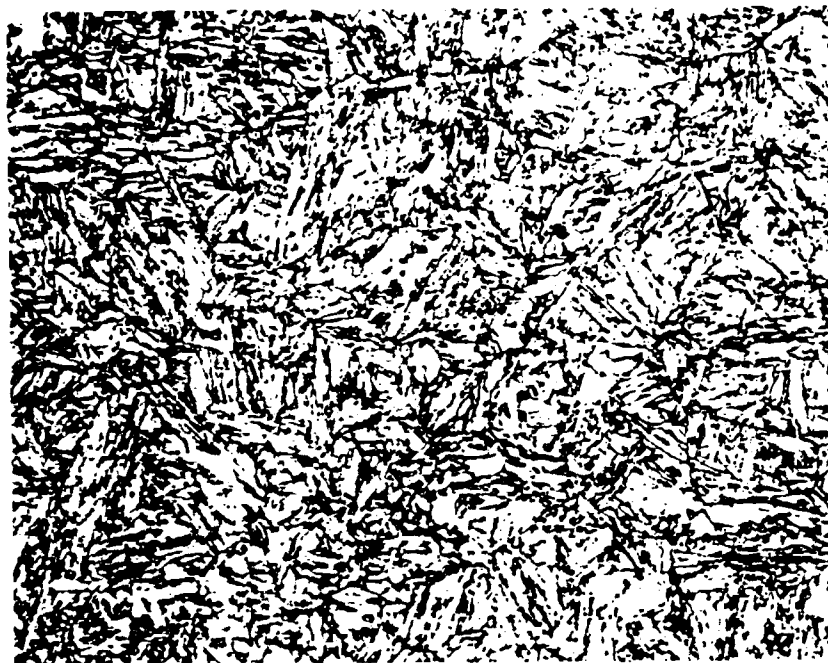
Figure 10a.   No-HIP sample revealing a tempered
              martensitic microstructure (1000X).

Figure 10b.   HIP sample revealing a tempered
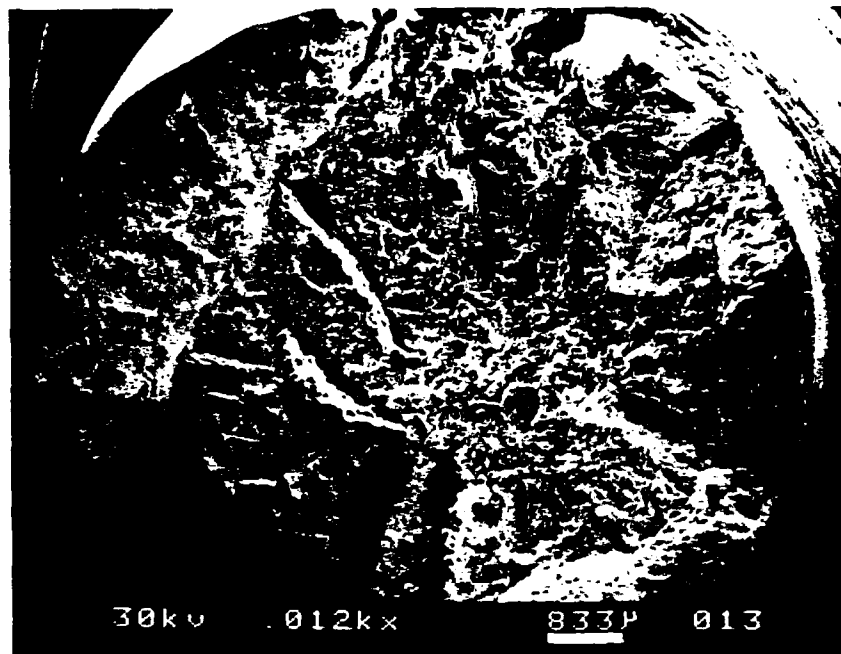   martensitic microstructure (1000X).

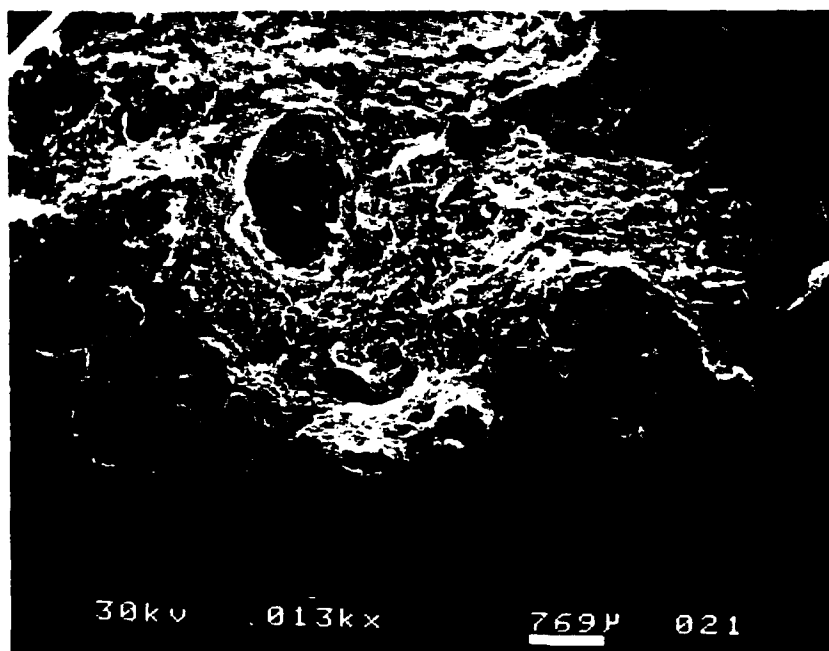Figure 11a. Overall fractograph of HIP fracture surface (12X).

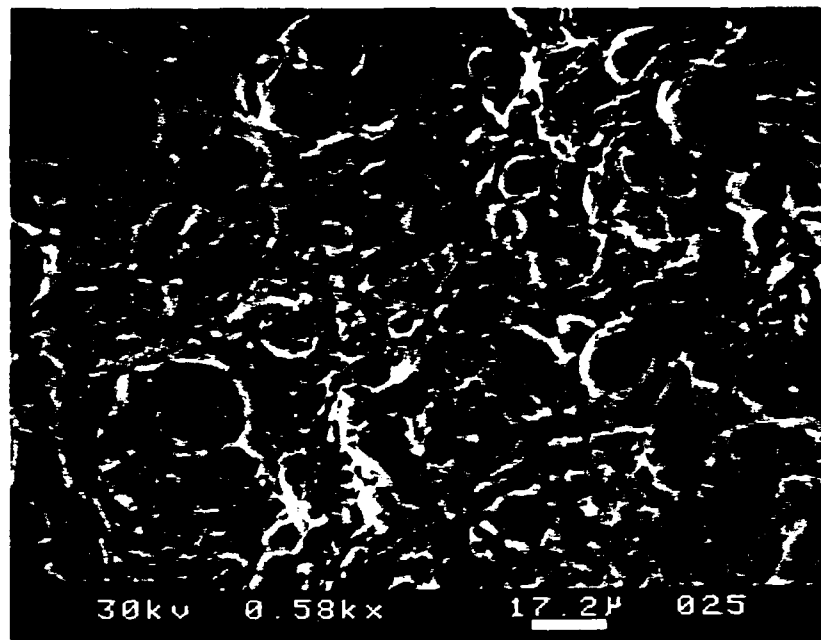Figure 11b. Overall fractograph of no-HIP fracture surface (13X).

Figure 11c. Dimpling on the fracture surface of the HIP sample (580X).
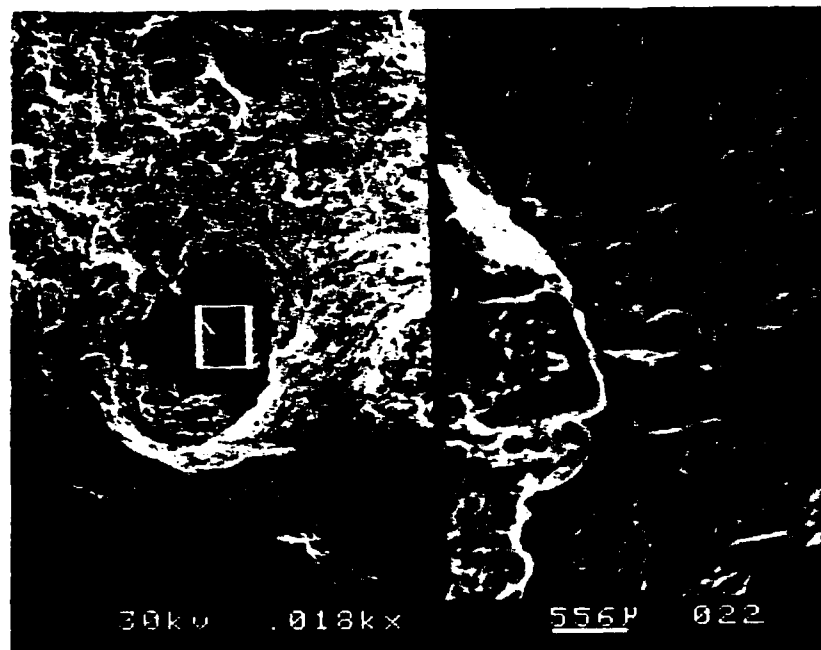

Figure 11d. Porosity observed on the fracture surface of the no-HIP sample at 18X. A magnified view of the pore at 180X.

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
CHIEF, DEVELOPMENT ENGINEERING DIVISION	
ATTN: SMCAR-CCB-D	1
-DA	1
-DC	1
-DM	1
-DP	1
-DR	1
-DS (SYSTEMS)	1
CHIEF, ENGINEERING SUPPORT DIVISION	
ATTN: SMCAR-CCB-S	1
-SE	1
CHIEF, RESEARCH DIVISION	
ATTN: SMCAR-CCB-R	2
-RA	1
-RM	1
-RP	1
-RT	1
TECHNICAL LIBRARY	5
ATTN: SMCAR-CCB-TL	
TECHNICAL PUBLICATIONS & EDITING SECTION	3
ATTN: SMCAR-CCB-TL	
DIRECTOR, OPERATIONS DIRECTORATE	1
ATTN: SMCWV-OD	
DIRECTOR, PROCUREMENT DIRECTORATE	1
ATTN: SMCWV-PP	
DIRECTOR, PRODUCT ASSURANCE DIRECTORATE	1
ATTN: SMCWV-QA	

NOTE: PLEASE NOTIFY DIRECTOR, BENET LABORATORIES, ATTN: SMCAR-CCB-TL, OF ANY ADDRESS CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES		NO. OF COPIES
ASST SEC OF THE ARMY RESEARCH AND DEVELOPMENT ATTN: DEPT FOR SCI AND TECH THE PENTAGON WASHINGTON, D.C. 20310-0103	1	COMMANDER ROCK ISLAND ARSENAL ATTN: SMCRI-ENM ROCK ISLAND, IL 61299-5000	1
ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN: DTIC-FDAC CAMERON STATION ALEXANDRIA, VA 22304-6145	12	DIRECTOR US ARMY INDUSTRIAL BASE ENGR ACTV ATTN: AMXIB-P ROCK ISLAND, IL 61299-7260	1

COMMANDER
US ARMY ARDEC
ATTN: SMCAR-AEE
    SMCAR-AES, BLDG. 321
    SMCAR-AET-O, BLDG. 351N
    SMCAR-CC
    SMCAR-CCP-A
    SMCAR-FSA
    SMCAR-FSM-E
    SMCAR-FSS-D, BLDG. 94
    SMCAR-IMI-I (STINFO) BLDG. 59
PICATINNY ARSENAL, NJ 07806-5000
	1
	1
	1
	1
	1
	1
	1
	1
	2
		COMMANDER
		US ARMY TANK-AUTMV R&D COMMAND
		ATTN: AMSTA-DDL (TECH LIB)
		WARREN, MI 48397-5000
		
		COMMANDER
		US MILITARY ACADEMY
		ATTN: DEPARTMENT OF MECHANICS
		WEST POINT, NY 10996-1792
		
		US ARMY MISSILE COMMAND
		REDSTONE SCIENTIFIC INFO CTR
		ATTN: DOCUMENTS SECT, BLDG. 4484
		REDSTONE ARSENAL, AL 35898-5241
			1
			
			1
			
			2

DIRECTOR US ARMY BALLISTIC RESEARCH LABORATORY ATTN: SLCBR-DD-T, BLDG. 305 ABERDEEN PROVING GROUND, MD 21005-5066	1	COMMANDER US ARMY FGN SCIENCE AND TECH CTR ATTN: DRXST-SD 220 7TH STREET, N.E. CHARLOTTESVILLE, VA 22901	1
DIRECTOR US ARMY MATERIEL SYSTEMS ANALYSIS ACTV ATTN: AMXSY-MP ABERDEEN PROVING GROUND, MD 21005-5071	1	COMMANDER US ARMY LABCOM MATERIALS TECHNOLOGY LAB ATTN: SLCMT-IML (TECH LIB) WATERTOWN, MA 02172-0001	2
COMMANDER HQ, AMCCOM ATTN: AMSMC-IMP-L ROCK ISLAND, IL 61299-6000	1		

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER, US ARMY AMCCOM, ATTN: BENET LABORATORIES, SMCAR-CCB-TL, WATERVLIET, NY 12189-4050, OF ANY ADDRESS CHANGES.

	NO. OF COPIES		NO. OF COPIES
COMMANDER US ARMY LABCOM, ISA ATTN: SLCIS-IM-TL 2800 POWDER MILL ROAD ADELPHI, MD 20783-1145	1	COMMANDER AIR FORCE ARMAMENT LABORATORY ATTN: AFATL/MN EGLIN AFB, FL 32542-5434	1
COMMANDER US ARMY RESEARCH OFFICE ATTN: CHIEF, IPO P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709-2211	1	COMMANDER AIR FORCE ARMAMENT LABORATORY ATTN: AFATL/MNF EGLIN AFB, FL 32542-5434	1
DIRECTOR US NAVAL RESEARCH LAB ATTN: MATERIALS SCI & TECH DIVISION CODE 26-27 (DOC LIB) WASHINGTON, D.C. 20375	1 1	METALS AND CERAMICS INFO CTR BATTELLE COLUMBUS DIVISION 505 KING AVENUE COLUMBUS, OH 43201-2693	1

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING
       CENTER, US ARMY AMCCOM, ATTN: BENET LABORATORIES, SMCAR-CCB-TL,
       WATERVLIET, NY 12189-4050, OF ANY ADDRESS CHANGES.